

Iris Biometric Analysis under Occlusion

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By

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Electrical Engineering

National Institute Of Technology, Rourkela

July 1, 2016

Prof. Supratim Gupta

(Supervisor)

Supervisor's Certificate

This is to certify that the work presented in this dissertation entitled “Iris Biometric Analysis under Occlusion” by Ashish Pandey, Roll Number: 112EE0248, is a record of original research carried out by him under my supervision and guidance in partial fulfilment of the requirements of the degree of Electrical Engineering. Neither this dissertation nor any part of it has been submitted for any degree or diploma to any institute or university in India or abroad.

Declaration of Originality

I, Ashish Pandey, Roll Number: 112EE0248 hereby announce that this thesis entitled " Iris Biometric Analysis under Occlusion " symbolizes my original work carried out as an undergraduate student of NIT Rourkela and, to the best of my understanding, it contains no material formerly printed or on paper by another person, nor any material existing for the award of any other degree or diploma of NIT Rourkela or any other Institution. Any contribution made to this research by others, with whom I have worked at NIT Rourkela or elsewhere, is explicitly acknowledged in the thesis. I have also submitted my original B.tech research record book to the committee for evaluation of my thesis.

I am fully aware that in case of any non-compliance detected in the future, NIT Rourkela may withdraw the degree awarded to me on the basis of the present report.

July 1, 2016

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Abstract

Iris is one of the most dependable biometric trait used for human's recognition. Iris recognition validates a person's identity by comparing the unique flowery patterns of the iris with that of the available database. The performance of the iris biometric reduces considerably if any occlusion like spectacles, glare corrupt the iris. In this project, we use image inpainting to alleviate the problem of occlusion pixels. This project is composed of stages which include, iris image acquisition, image inpainting, image pre-processing, feature extraction, matching with database and finally decision making. The algorithm for image inpainting is based on texture analysis using mean filter and the algorithm for iris recognition is based conceptually as used by R. P. Wildes. The result of the proposed (improved) iris recognition system have been found to be quite promising even in case of occlusion.

Key words: Biometric, iris pattern, occlusion, image inpainting, mean filter, iris localization.

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1. Introduction

1.1. Biometric Technology

Biometrics is the technology of identification of an individual using his physical and behavioural features. Physical features include facial, fingerprint, hand print, iris, DNA and retina. While voice, signature, walking style are categories to behavioural include [2, 9]. Why iris??? As irises are stable throughout life and it is visibly distinguishable between persons. Iris Recognition is the technique of examining the flowery pattern of the individual's iris by comparing it with others iris. The automated system for iris recognition is existing since 1994 but it is relatively new.

Iris, eye muscle that controls the pupil diameter according to the light intensity that finally results to the amount of light reaching retina [1, 4, 7]. Melatonin pigment are responsible for its colour typically ranging between brown, hazel, green, gray or blue. The colour and the design of iris are genetically dependable. However, the details of the flowery iris pattern are genetically non-transformable. During the prenatal age, iris start forming through the process of compact folding of tissue layer in embryo and after birth, its rambling occurs thus resulting in flowery pattern formation. Iris pattern are stable throughout the life.

An iris biometric system can be started by taking a digital coloured image of human eye. The iris image may then be cleared so that the most obsoleting features such as eyelashes, light, noise etc. can be reduced. Using some mathematical functions, digital coloured image is being transformed to biometric template. Then, transformed template are efficiently normalized for matching. Biometric systems use two steps of operations. The first step of operation consists of iris image registration, which enrolls the new iris image template in existing database while second step of operation consists of iris verification, which matches the iris template with database templates. Highly unique features will give good performance as biometric such as using iris, dna, retina. Due to uniqueness and consistency of comparing feature, the chances of having same characteristic in two persons are reduced as in case of iris, there is chance of matching two persons iris in 10^{78} persons.

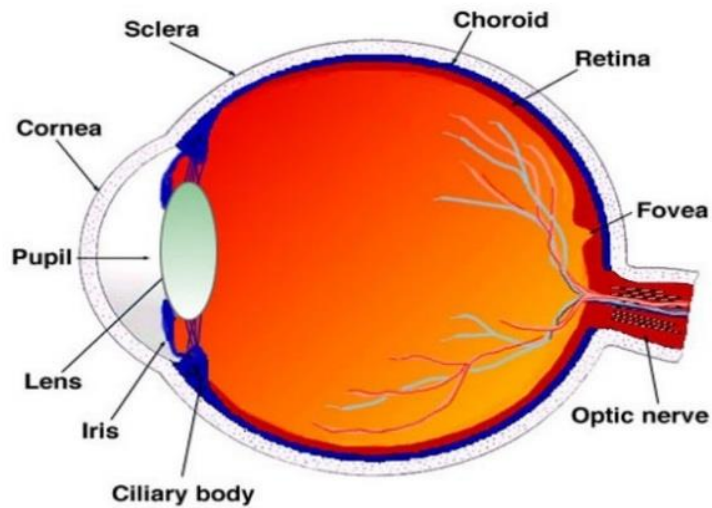


Figure 1: A sectional view of Human Eye

1.2. The Human Iris

Iris of the human eye is a colourful fine band of muscles, almost concentric circle in the eye with pupil in its centre. The iris of eye is responsible for varying the extent of the pupil boundary and allows the amount of light touching retina. For controlling the amount of light arriving the retina of the eye, the iris associated muscles either contract or dilute the inner area of the iris or called pupil [4].

Iris is made of two layer, front pigmented cells known as stroma and pigmented epithelial cells [7]. The sphincter muscle is connected with stroma, which not only regulates the compactness of the pupil and dilator muscles, but also controls the radially broadening of the pupil. The iris has mainly two areas: the pupillary zone, that encircles the pupil and the ciliary zone, that is near the outer boundary [9].

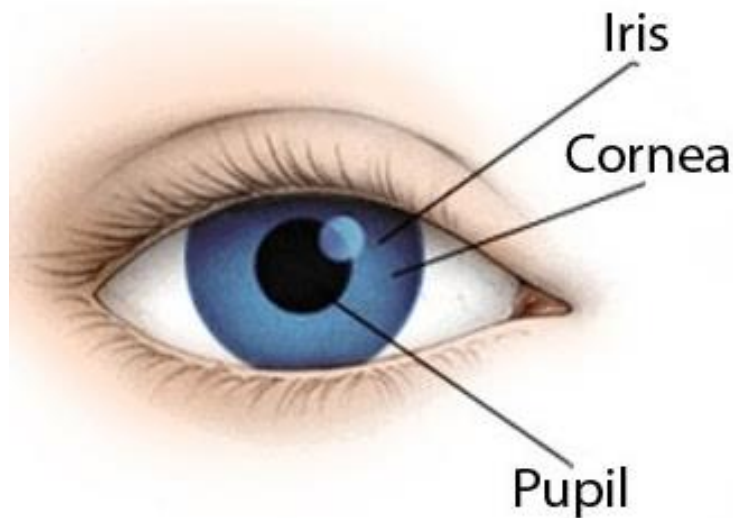


Figure 2: An external view of the Human Eye

1.3. Iris Recognition

The iris of the human eye is a highly protected organ which is visible from a distance and those flowery patterns are very unique from other irises and remain unchanged all over the life of that Human. Its high individuality and constancy, which makes it a good verification option for biometric identification of persons. These iris image patterns can be cropped out as a template using digital image processing methods which can use a gray image of the human eye and then that template can be enrolled for further evaluations in a database. Mathematical functions are used for coding the iris biometric template. If an individual wants to be verified, then first he should capture his eye in a digital method, and then an iris biometric template can be coded for the iris part of the human eye. This iris template, which is currently captured, is matched with the iris template of the database using mathematical comparing methods for verification of the person.

The first such iris recognition systems which had been proposed in the 1990's that Prof. J. Daugman [5] (University of Cambridge, Cambridge, United Kingdom) executed a working model on the concept, as shown by the patent of Flom and Safir [8]. After Daugman, there are other models on different concepts are also proposed making the result more efficient.

On comparing the other existing biometric technology, Iris recognition have the most accurate and good performance. The other technologies mainly based on features such as fingerprint, facial pattern, signature style, walking style and speech recognition where behavioural characteristics can be faked and pattern of iris can't be copied.

1.4. Objective

The main aim of the project is to develop a system for an iris biometric system under occlusion that can recognize after resolving occlusion and verify human identity using their iris flowery patterns as a biometric identification. Image inpainting is used for resolving any light reflections from iris part of human eye for better accuracy.

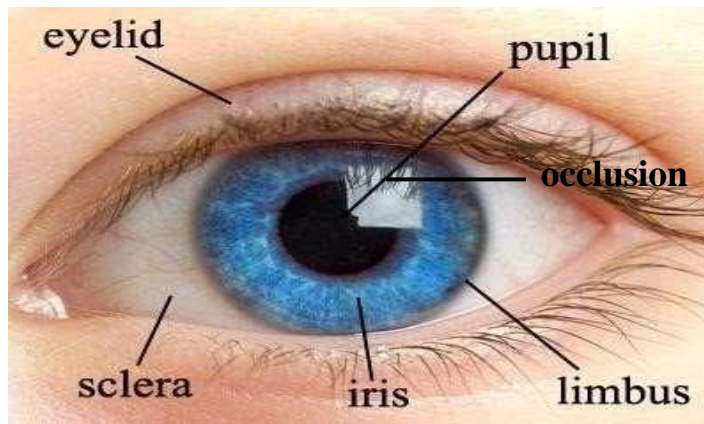


Figure 3: Human Eye with occlusion in iris part

The system is divided into a number of sub-parts:

1. Image Acquisition (capturing or taking input image)
2. Image Inpainting (restoration of missing or corrupted image)
3. Image segmentation (localization of the iris part in eye image)
4. Image registration (scaling and rotation are applied on the segmented iris part and then normalization)
5. feature encoding (transforming the image into a biometric template using mathematical models)
6. Matching (comparison of templates).

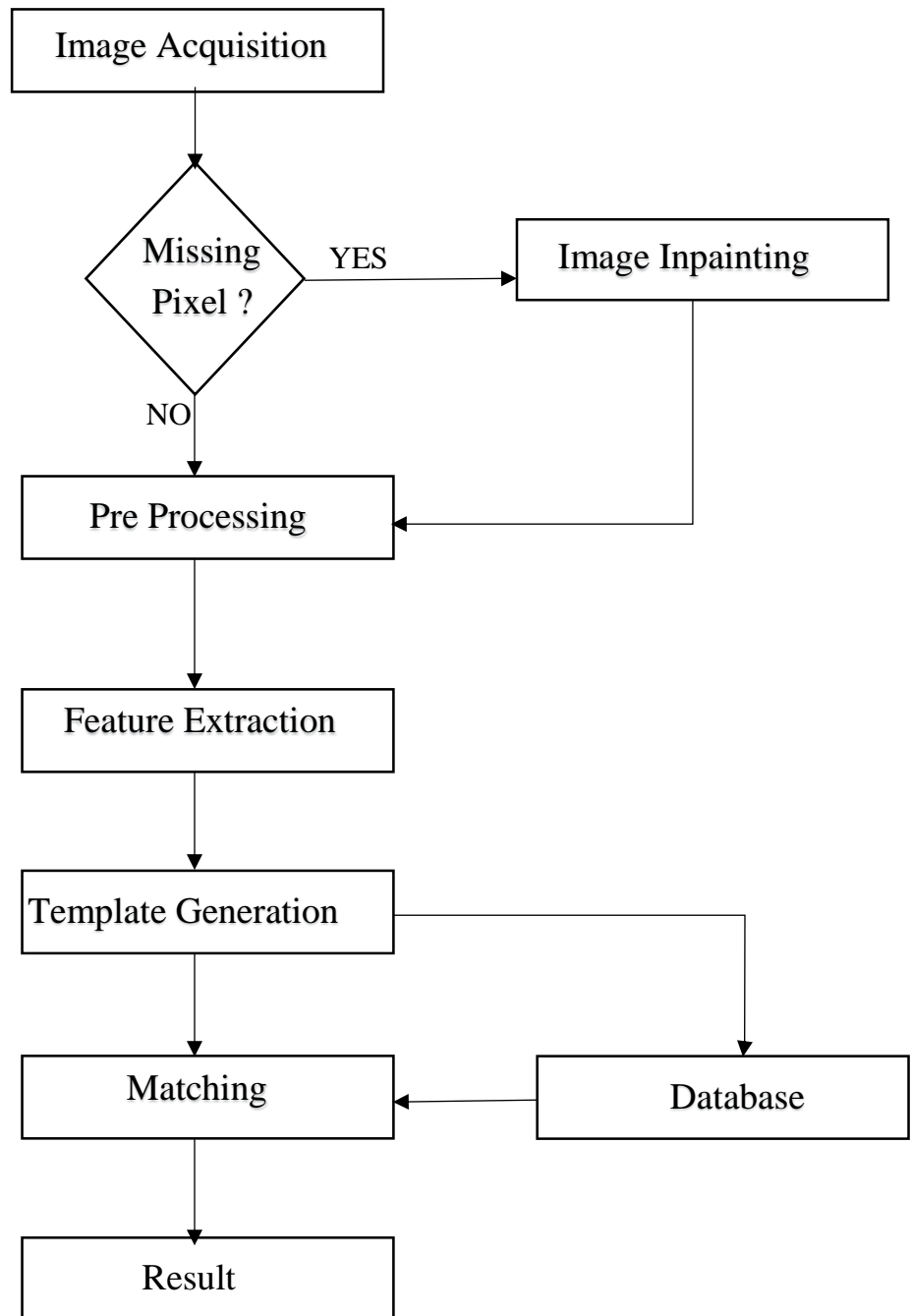


Figure 4: Flow chart of process

This algorithm is to be checked using some database such as UBIRIS [3] and analysis were to be observed.

2. Image Inpainting

Most problems with the old image or new images is that they usually get corrupted by noise, dust and strain on the glass of the scanner, damage due to scratching or something unwanted which is needed to be removed for better outlook. It is mainly used for restoration of painting at museum or in editing of old video. The algorithm of image denoising and image deblurring do not apply to damaged images because inpainting are used for large damaged images which they can't restore. Restoration or recovery of old lost, damaged part of the image is known as image inpainting.

This can be done by using two methods, image inpainting and texture analysis, first means restoration of missing pixels of image or damaged parts in such a way that the observer can't know the difference while the second one is filling the missing pixels using knowledge of the neighbourhood pixels. Normally, texture inpainting fails in multicolour point due to intensity gradient. In iris biometric, the iris feature to be used are gray image and also for texture inpainting. Damaged images are obtained using windows paint. The pixel values are checked, when it is 1 then inpainting function is called, else the program moves to next step, pre-processing.

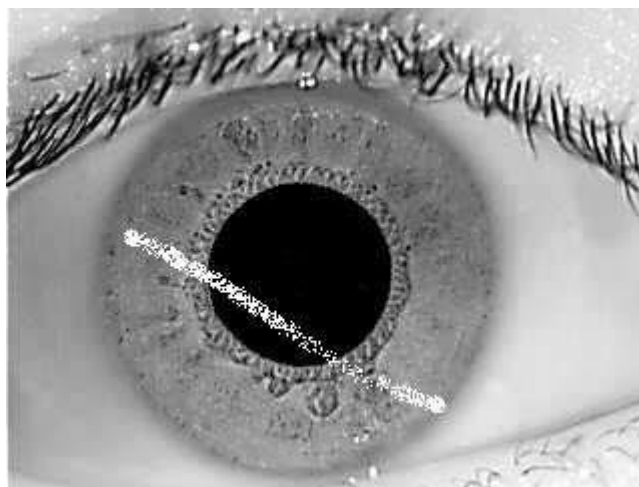


Figure 5: Corrupted eye image

Mean Filter is a linear and most common filter in which the average of all elements were taken. According to the pixel having occlusions, the number of iterations will increase and similarly, the time also increase. If the missing pixels are less, it will take nearly 15 seconds. After considering the damaged pixels, mean filter is only applied at that pixel and it will re-check the missing pixels. It will be running till missing pixel numbers are same in two iterations. This takes just two to three iterations, but a large number of iterations are required to make pixel value saturated. This method will leave boundary pixels.

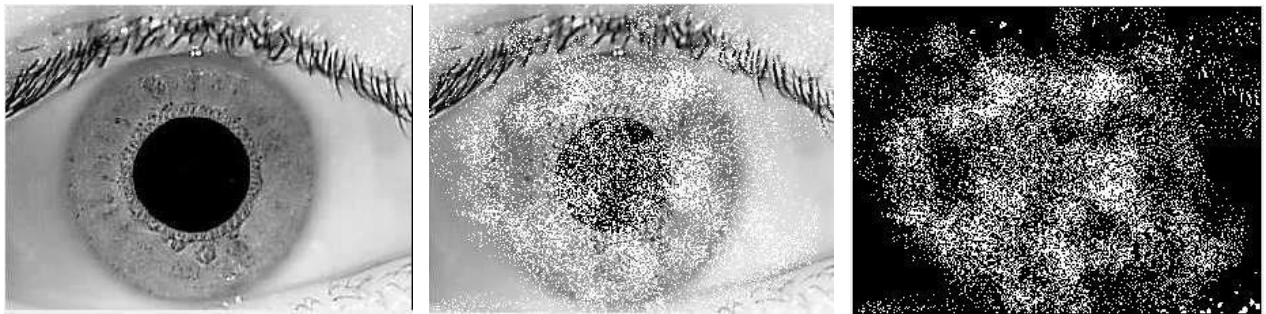


Figure 6: (a) original image, (b) masked image, (c) binary missing image

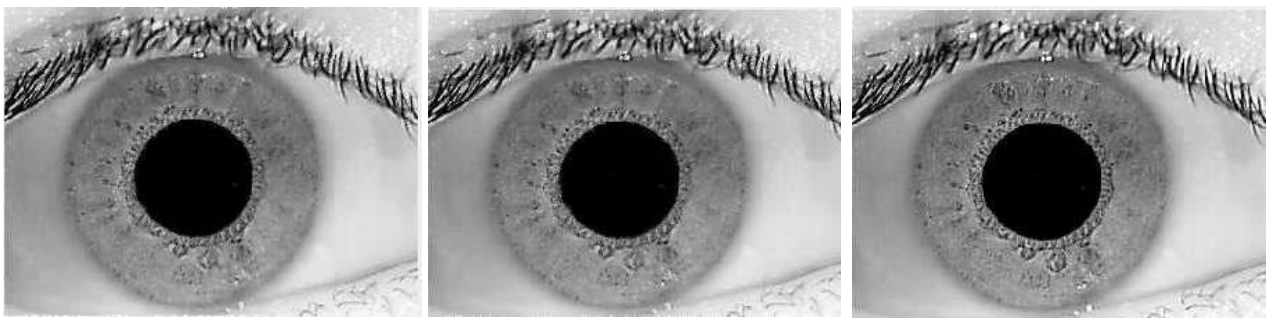


Figure 7: (a) after first iteration, (b) after 10 iterations, (c) after 75000 iterations

2.1. Algorithm

Steps of the algorithm are:

1. Determine the number of missing pixels.
2. Mean filter is applied at only the missing pixels.
3. Run mean filter till the pixel value doesn't get saturated.
4. Re-check the missing pixels and again compute mean filter values for those left missing pixels.
5. Stops when there are no missing pixels.

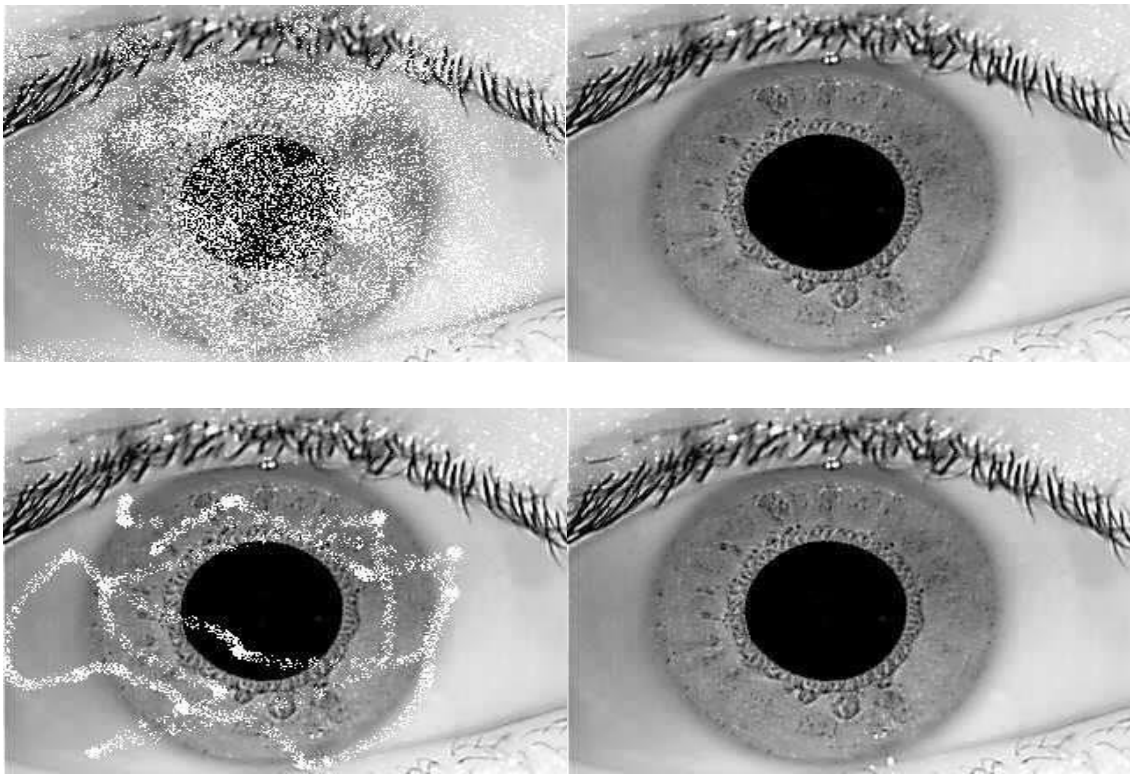


Figure 8: a) Corrupted image (left), b) Recovered image (right) for both set of image

3. Segmentation

The aim is to localize the iris part and isolate it from the other rest of the iris image. The isolate area is between two non-concentric circle of the human eye, one making iris boundary or iris outer boundary and the other making pupil boundary or iris inner boundary. Obstacles such as eyelashes or eyelids that cover upper and lower part of the iris, which have to be removed. Visible reflections that may occur in the iris, which corrupt the iris pattern which can be cleared during the last stage of image inpainting. So the method used must reduce noises and locate the non-concentric iris part out of digital coloured images or gray image of eye of human else rest of the image may worsen the performance of the system.

3.1. Wildes methodology

The Wildes iris recognition system completes segmentation as following steps:

1. Binary edge mapping function is applied on image intensity function
2. The gradient-based edge detection method is used to recover the binary edge mapping function. Laplacian of Gaussian filter is used.

The edge detection method is mapping the image from 2D array of pixels to detect of a set a curve or lines or contours using the gradient method, which uses the noise suppression method, filter of contrast and edge localization methods. Edge detection can also be carried out using the binary edge method converting image into binary and detecting the boundaries.

In this method, threshold of magnitude of gradient of the image intensity function is applied that is

$$|\nabla G(x, y) * I(x, y)| \quad (1)$$

$$\text{where } \nabla \equiv \left(\frac{\partial}{\partial x}, \frac{\partial}{\partial y} \right)$$

while

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{(x-x_0)^2 + (y-y_0)^2}{2\sigma^2}} \quad (2)$$

where, (x_0, y_0) is the co-ordinates of centre of circle
and σ is the standard deviation.

Using Laplacian of Gaussian filter in edge detection is a method for blob detection, which aims to detect different shapes in image that differ in properties such as colour, brightness in respect to their surroundings. Blob detection has mainly two classes of method: (1) derivative method and (2) local maxima method. Laplacian of Gaussian filter is mathematically defined in equation 1 and equation 2.

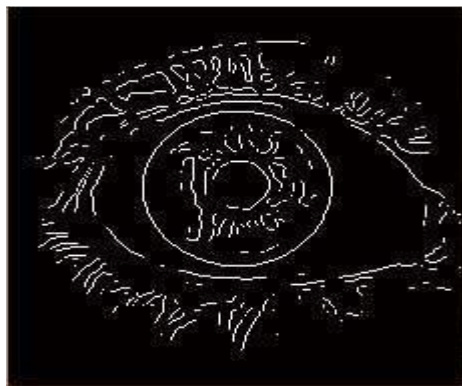


Figure 9: Showing Edge Detection

3.2. Hough Transform

Hough transforms [9] feature extraction technique of digital image processing or computer vision. The basic aim of this technique is to find curves, shapes, lines and other polygons that can be defined by

mathematical functions such as circles and other polynomial functions having higher degree. Hough transformation is normally used for detection of lines and circles. Hough transformation is explained by Richard Duda and Peter Hart in year 1972 in their paper as “Generalized Hough transformation” [9]. Circular Hough Transformation is a basic technique that uses the same concept as of Hough transformation. Its main feature is to detect the boundary of circles using the equation 5. When (x_i, y_i, r) satisfies the equation 5 with a range of radius given, it will detect the circle. For instance, the detection of the circle can be easily done in an image by using the minima marked by binary edge method which are the maxima for circle formed by using Hough transformation. The Circular Hough transformation technique uses the concept of three or more lines of the same length passing through same point called centre and the line is equally divided in half by centre. According to Wildes [4] concept based algorithm, this technique to localize irises between the boundary lines which are not concentric.

Hough transform is used by taking the obtained points using Laplacian of Gaussian filtered edge method as $(x_i, y_i); i = 1, 2, \dots, n$ and thus, this transform can be defined mathematically as:

$$H(x_c, y_c, r) = \sum_{i=1}^n h(x_i, y_i, x_c, y_c, r) \quad (3)$$

where

$$h(x_i, y_i, x_c, y_c, r) = \begin{cases} 1, & \text{if } g(x_i, y_i, x_c, y_c, r) = 0 \\ 0, & \text{Else} \end{cases} \quad (4)$$

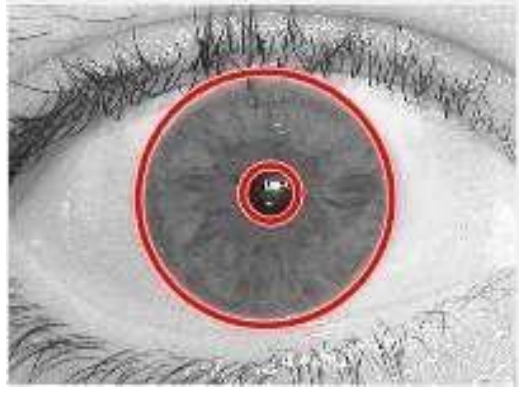


Figure 10: Showing Circle as the boundaries of Iris using Hough Transform

Circles are showing boundaries of the iris. The circle function (g) is mathematically defined as:

$$g(x_i, y_i, x_c, y_c, r) = (x_i - x_c)^2 + (y_i - y_c)^2 - r^2 \quad (5)$$

Taking assumption for a circle through its centre (x_c, y_c) having r as radius of the circle and the co-ordinate points are falling on that circle, which results in zero value as of equation 5 will make the defined circle.

The algorithm based on Circular Hough Transformation is as follows:

1. Creation of storage space for each pixel, which is initially taken as 0.
2. For each (x_i, y_i) edge point in an image, increase the value for ' x_c ' as x-axis co-ordinate of centre of circle, which satisfies the equation 5.
3. Similarly, for values of ' y_c ' as y-axis co-ordinate of centre of circle, which satisfies the equation 5.
4. Now searching the local maxima in binary edge map of the intensity function for image.

3.3. Implementation

There are numerous methods available but for localizing the iris in eye image, Circular Hough Transform (CHT) was used due to its robust nature that is also tolerant to noise. It uses binary image to find the iris boundary. The horizontal and vertical gradients were equally weighted such that it forms the boundary for the inner iris/pupil boundary.



Figure 11: Feature extracted from eye image

To make detection of circle method more efficient, initially, the boundary between sclera and the iris were detected and then, the boundary between pupil and iris were detected, instead of searching in the whole image for boundary. After detecting inner and outer boundary, total six parameters were founded including centre point (x, y) and radius r for both boundaries.

Eyelids and eyelashes are ignored by using parabolic lines which also use linear Hough transformations. Edge mapping was done by an edge detection function, which depend Laplacian of Gaussian filter and the horizontal gradient information was only taken. Instead of using parabolic Hough transformation, linear Hough transformation is used to reduce the parameters and makes the process less complex.

4. Image Registration

After having segmentation effectively of the iris part, the next stage is to apply scaling and rotation of template. The basic aim behind image registration is apply scaling and rotation as to get featured template of the same dimension before matching as dimensional problem may arise due to pupil dilution or contraction. Pupil dilution or contraction may arise due to variation of illumination levels that falls on the eye. The other reasons are due to variation of object distance, camera inclination, head angle and even the natural eye rotation. The following methods will make the iris templates which have same dimensions such that there is no variation due to different conditions and time.

Image registration is the methods of positioning two or more templates of the same dimensions using a common point. This process involves scaling and rotation of iris template by applying geometric transformations to align the images.

The process will also give compensated value for the rotational and scaling. The scaling or resizing uses the bi-linear interpolating technique while the rotation function uses bilinear interpolation technique by changing the rotation by a one degrees in clockwise direction.

5. Feature Matching

For evaluating the goodness of match, wildes have used a typical method for matching template in iris biometric system. Wildes method is based on normalized correlation, which compares currently generated iris template with database iris templates. As mathematical function, normalized correlation can be expressed as:

Let $t_1[i, j]$ and $t_2[i, j]$ be two image template array of size $m \times m$.
mean:

$$\mu_1 = \left(\frac{1}{mm}\right) \sum_{i=1}^m \sum_{j=1}^m t_1[i, j] \quad (6)$$

and

standard deviation:

$$\sigma_1 = \sqrt{\left(\frac{1}{mm}\right) \sum_{i=1}^m \sum_{j=1}^m (t_1[i, j] - \mu_1)^2} \quad (7)$$

for the intensities function of t_1 . Also similarly, let μ_2 and σ_2 for intensity function of t_2 . Then, the normalized correlation can be mathematically expressed as:

$$\frac{\sum_{i=1}^m \sum_{j=1}^m (t_1[i, j] - \mu_1)(t_2[i, j] - \mu_2)}{mm\sigma_1\sigma_2} \quad (8)$$

Standard correlation is similar data as of normalized correlation but standard correlation is the maximum of all elements, however, normalized correlation also gives the data for small deviations in image intensity function that reduces the value as given by standard correlation. In application, normalized correlation value ranges from -1 to 1 in which 1 or -1 values having positive or negative relation between templates while 0 (zero) refer to no relation between template. Correlation values range from 0 to 1 with similar interpretations. This method is being used for the authentication job only. Taking images from different angles makes some pixels with no relations in same image pixels.

6. Graphical User Interface Development

For developing Graphical user interface (GUI), Guide function is used in MATLAB.

- Push button are used for giving input to GUI.
- For browsing Database image from Hard Disk, “Load Database” push button is implanted and a status bar is for displaying the number of images loaded in database.
- For loading of the verification image, “Test” push button is implanted that will open window for manual selection.
- Two axes are implanted for displaying the input image and output inpainted image. A status bar will show the number of pixels damaged or lost.
- Finally, “Compare” Push button is implanted for analysing the input image with Database images.
- There is status bar for displaying the result and number of iris matched.

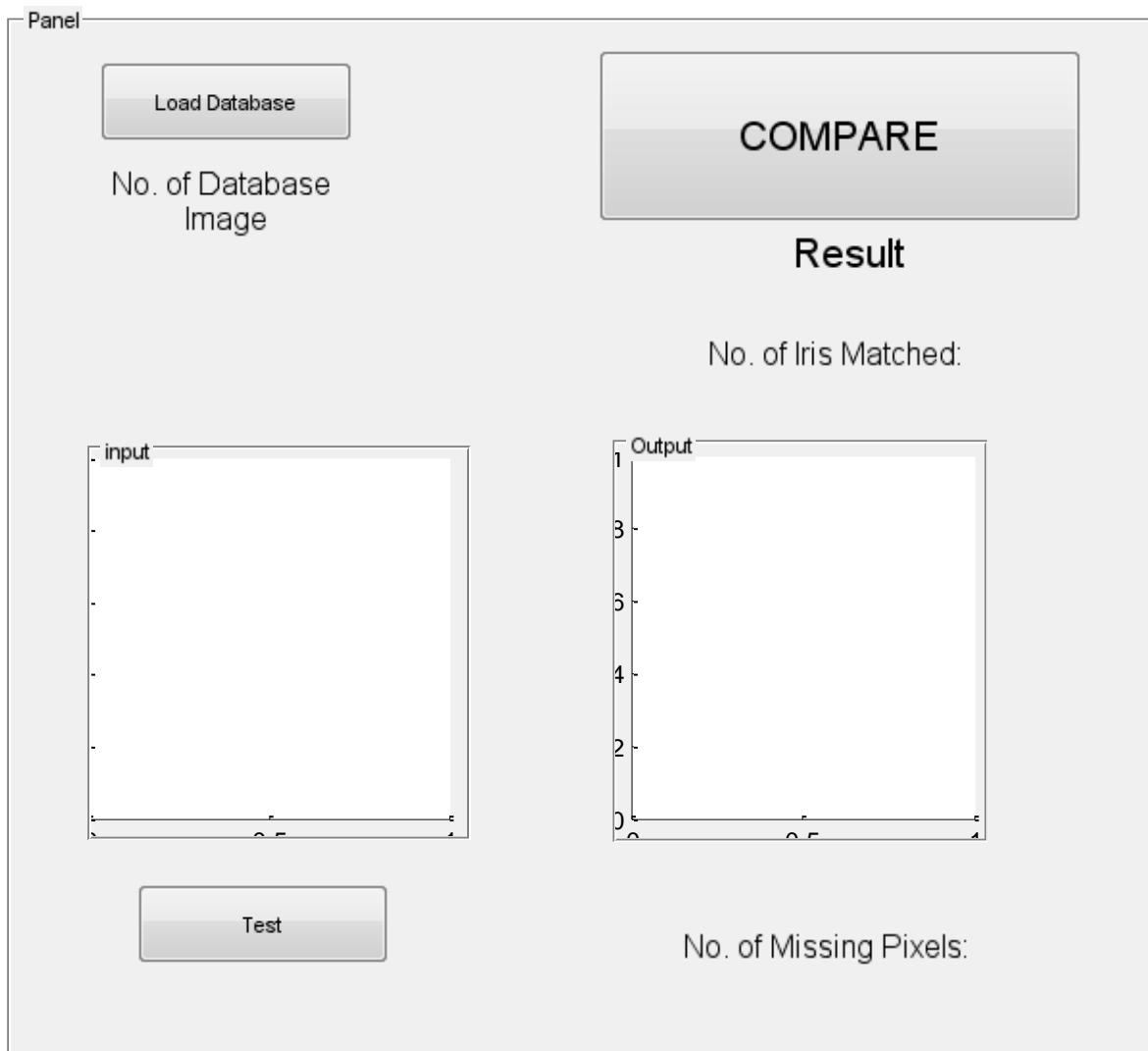


Figure 12: Sample GUI

7. Experimentation and Results

To validate the proposed algorithm, we have conducted experiments on UBIRIS [2] database. We have collected 57 uncorrupted iris images from 20 persons. Iris code was extracted from each of the 57 images using Wildes [4] algorithm. Each iris code was given a unique identification number so as to be used for verification application. The extracted iris codes were used to create a ground truth test bench for local database.

- Experiment 1

To validate the performance of the system, we collected randomly 10 images from the same database and extracted the iris code. These codes were matched with the test bench database, and corresponding identification number and number of matches was displayed. (Figure 17- 20)

- Experiment 2

To justify the statement that under occlusion the performance of the system decreases. We have taken 5 iris images and corrupted the image randomly using Windows Microsoft paint application. We extracted the iris code for the corrupted images and checked for a match in the test bench. There were no matches.

- Experiment 3

To validate the performance of the proposed method. We took the 5 corrupted images of experiment 2 and implemented the image inpainting. Iris code of the processed image are extracted and verified for a match. After inpainting, we found that the number of mismatches or no matches found were reduced significantly. (Figure 13- 16)

This method has zero unauthorized entry that is 0% false acceptance rate (FAR), FAR is the ratio of the number of false acceptances is to the total number of verification attempts taken and nearly 5 mistakes done by system to recognize that is nearly 9% false rejection rate (FRR), FRR is the ratio of valid inputs which are incorrectly rejected is to the total number of verification attempts taken which might get better as the number of irises enrolled increases.

8. Graphical User Interface (Result)

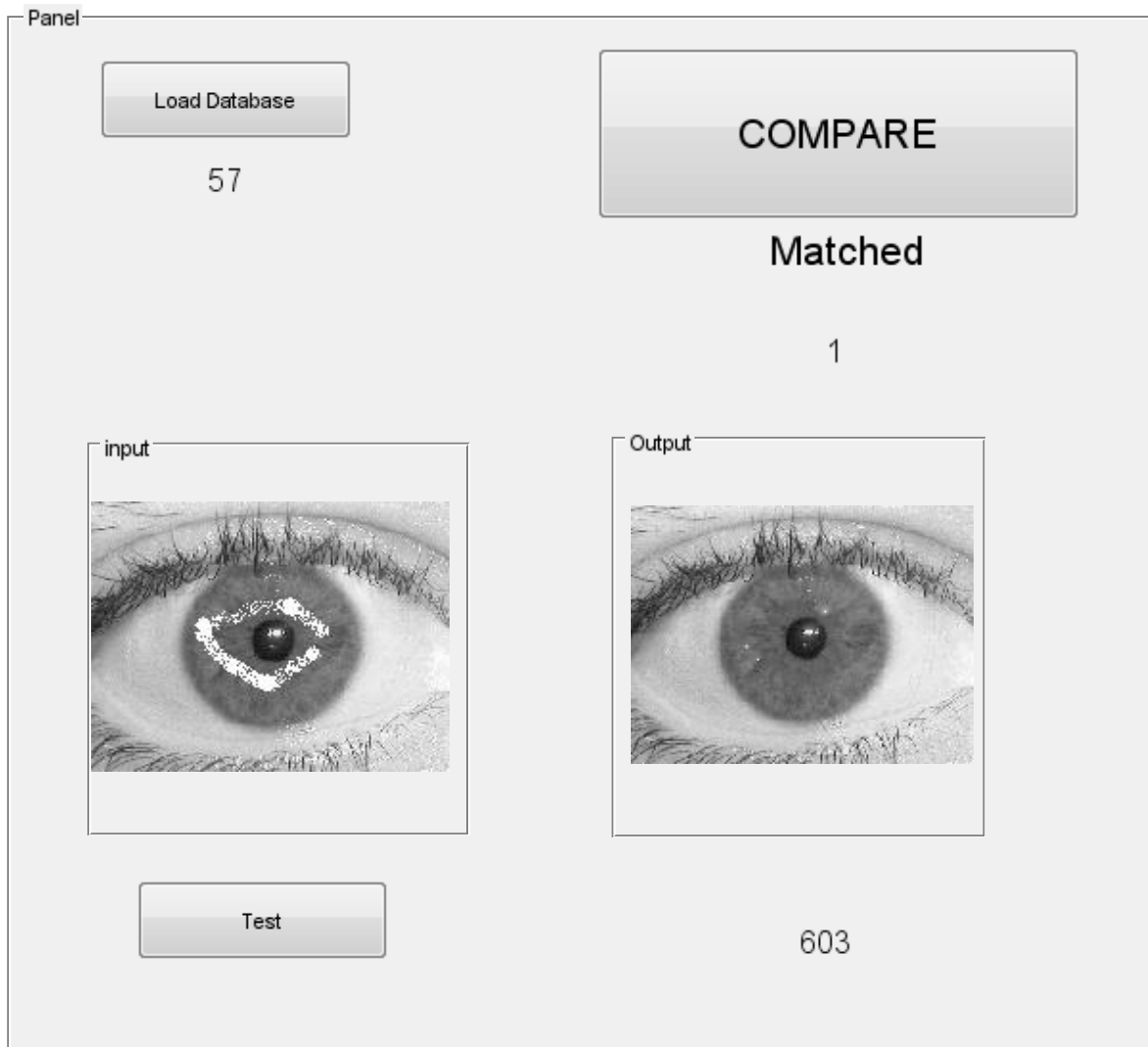


Figure 13: GUI showing image inpainting, output image and results (Example 1)

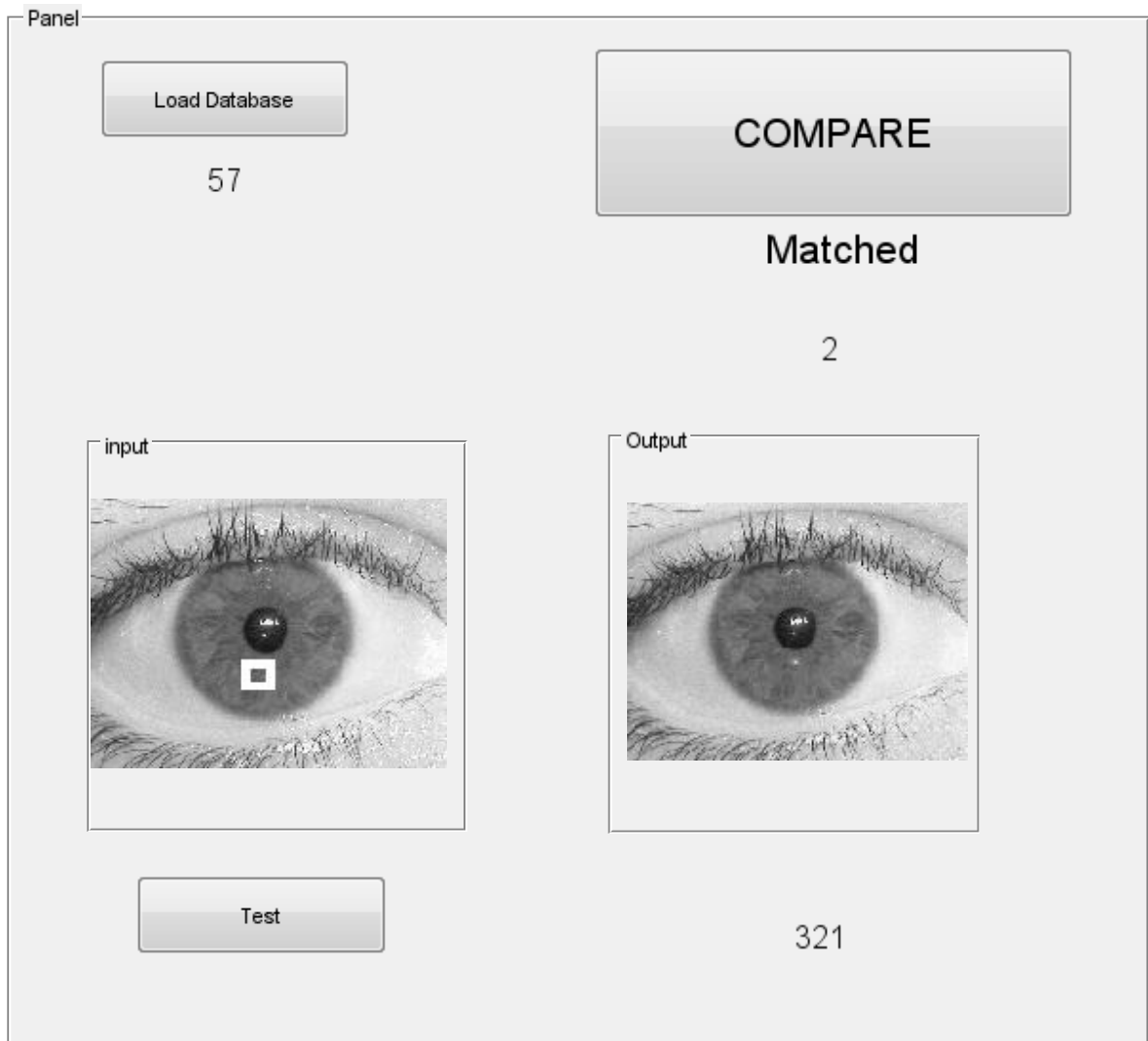


Figure 14: GUI showing image inpainting, output image and results (Example 2)

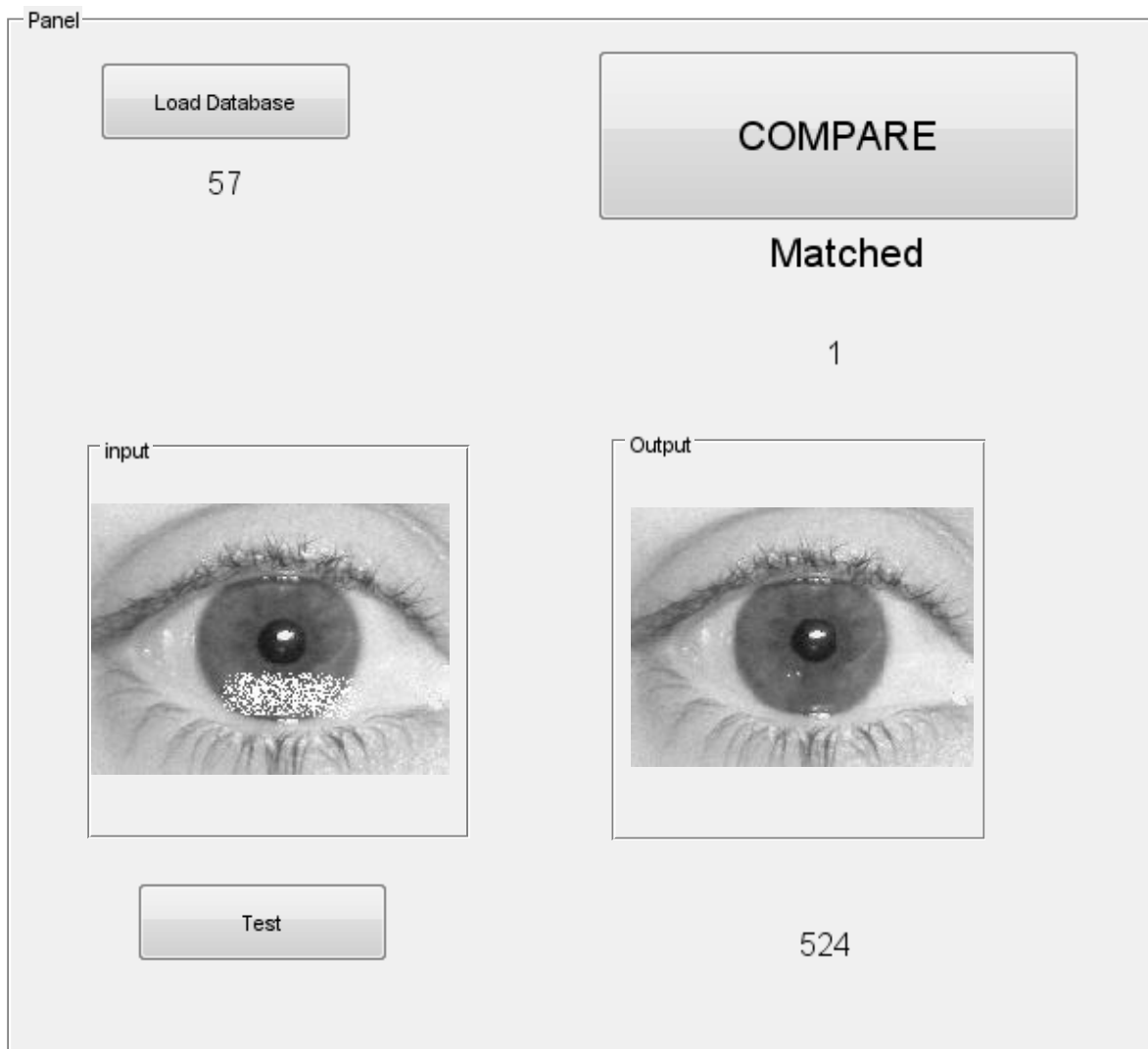


Figure 15: GUI showing image inpainting, output image and results (Example 3)

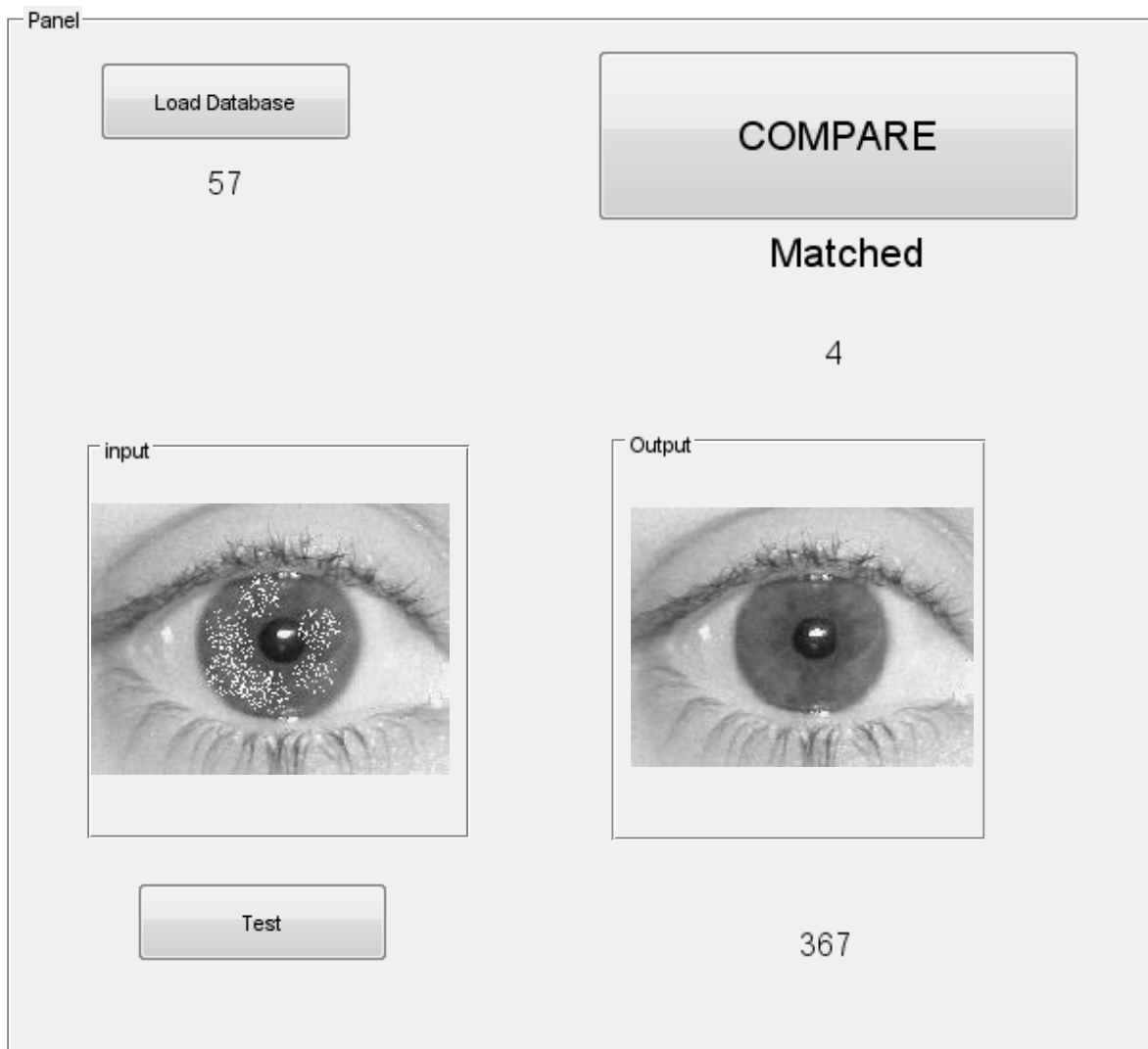


Figure 16: GUI showing image inpainting, output image and results (Example 4)

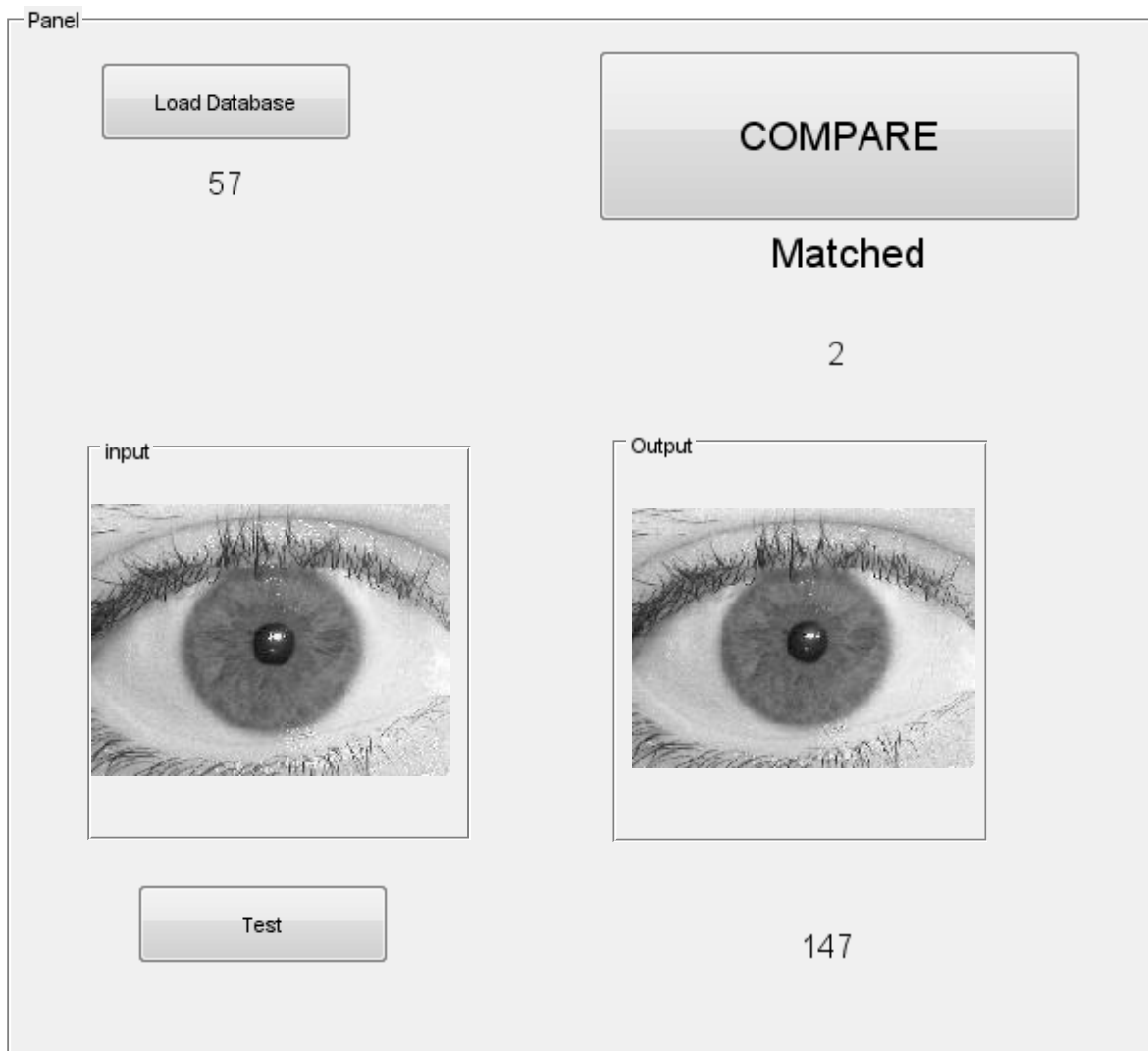


Figure 17: GUI showing input image, output image and results (Example 5)

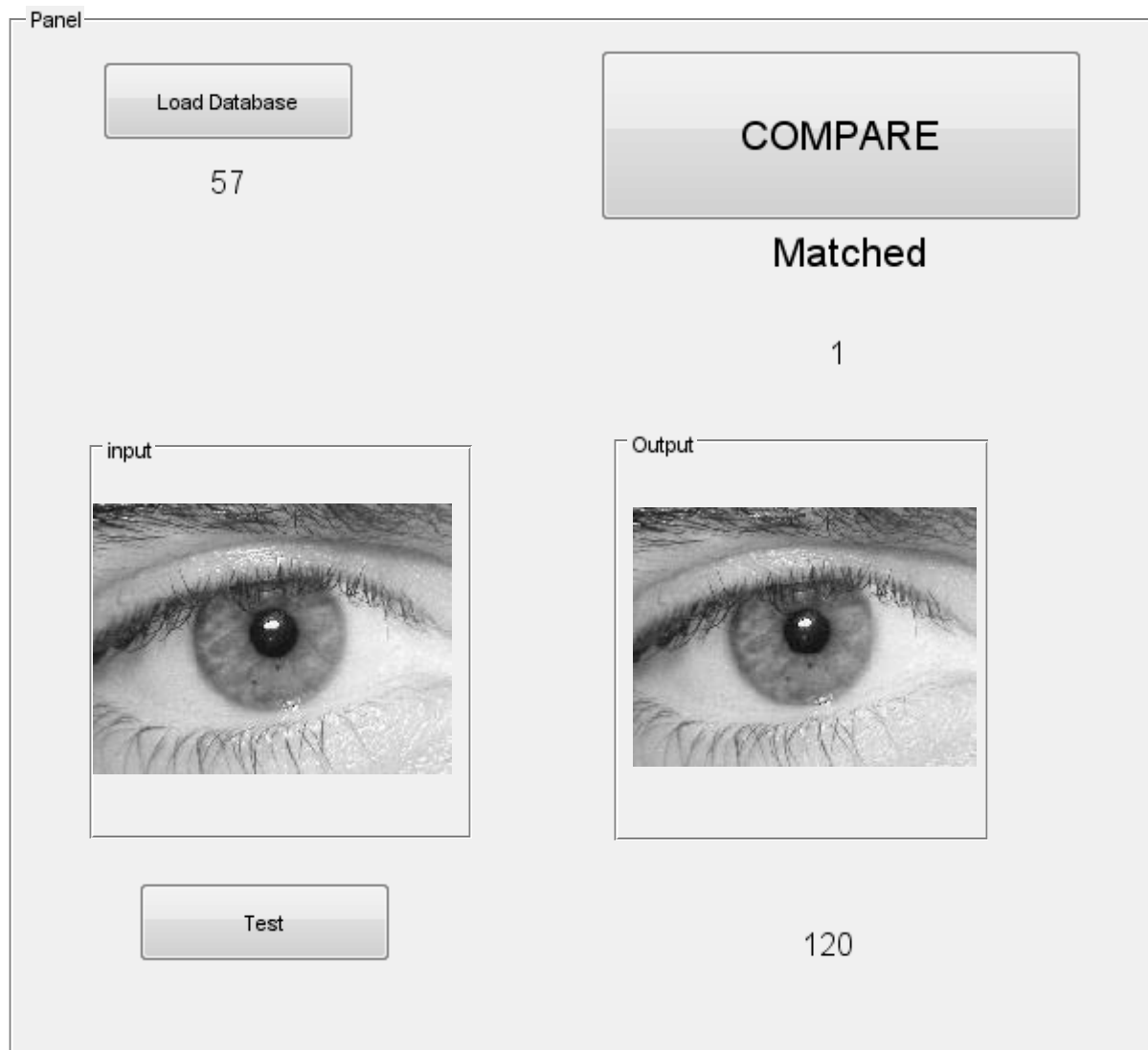


Figure 18: GUI showing input image, output image and results (Example 6)

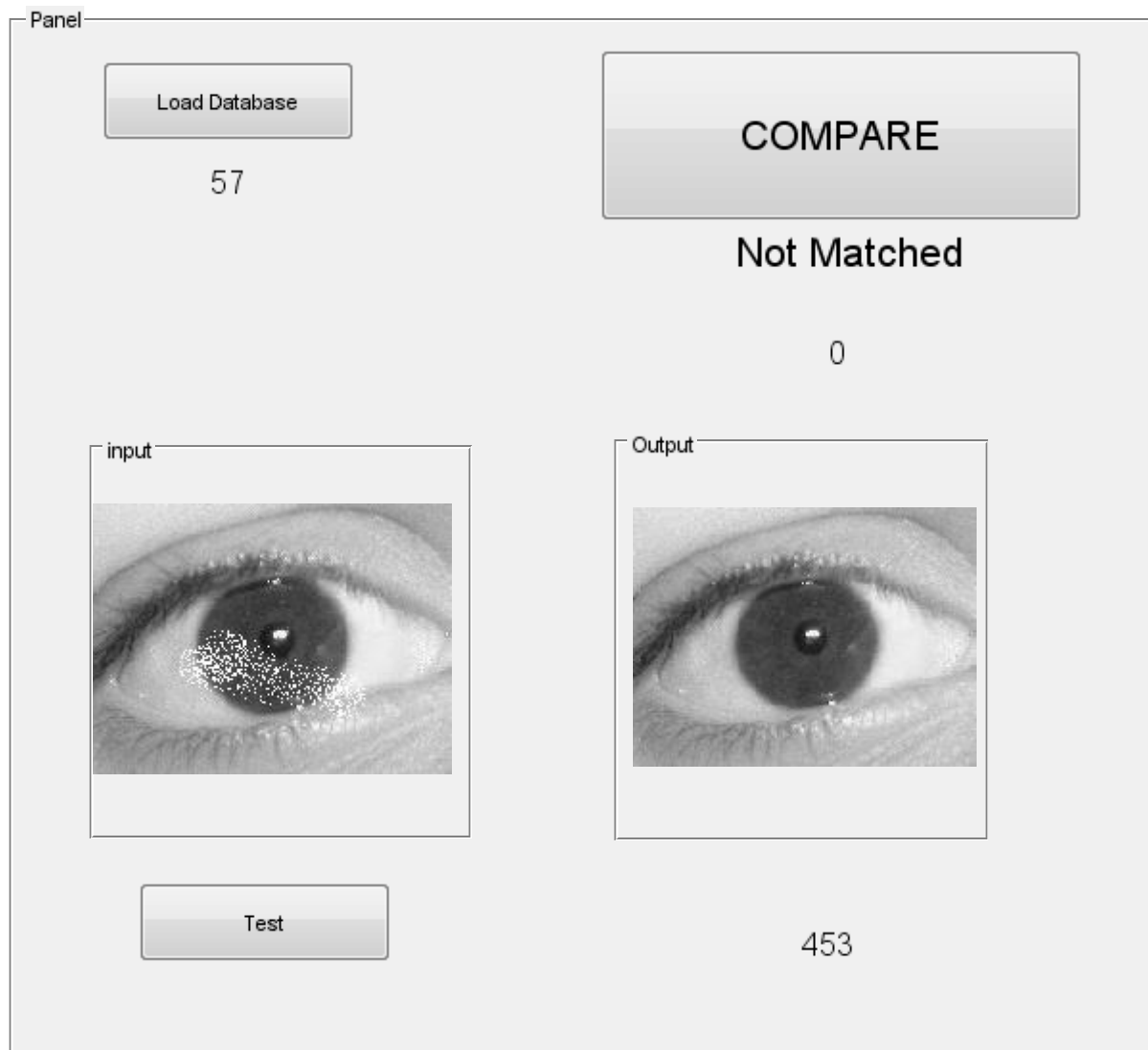


Figure 19: GUI showing different input image, output image and results (Example 7)

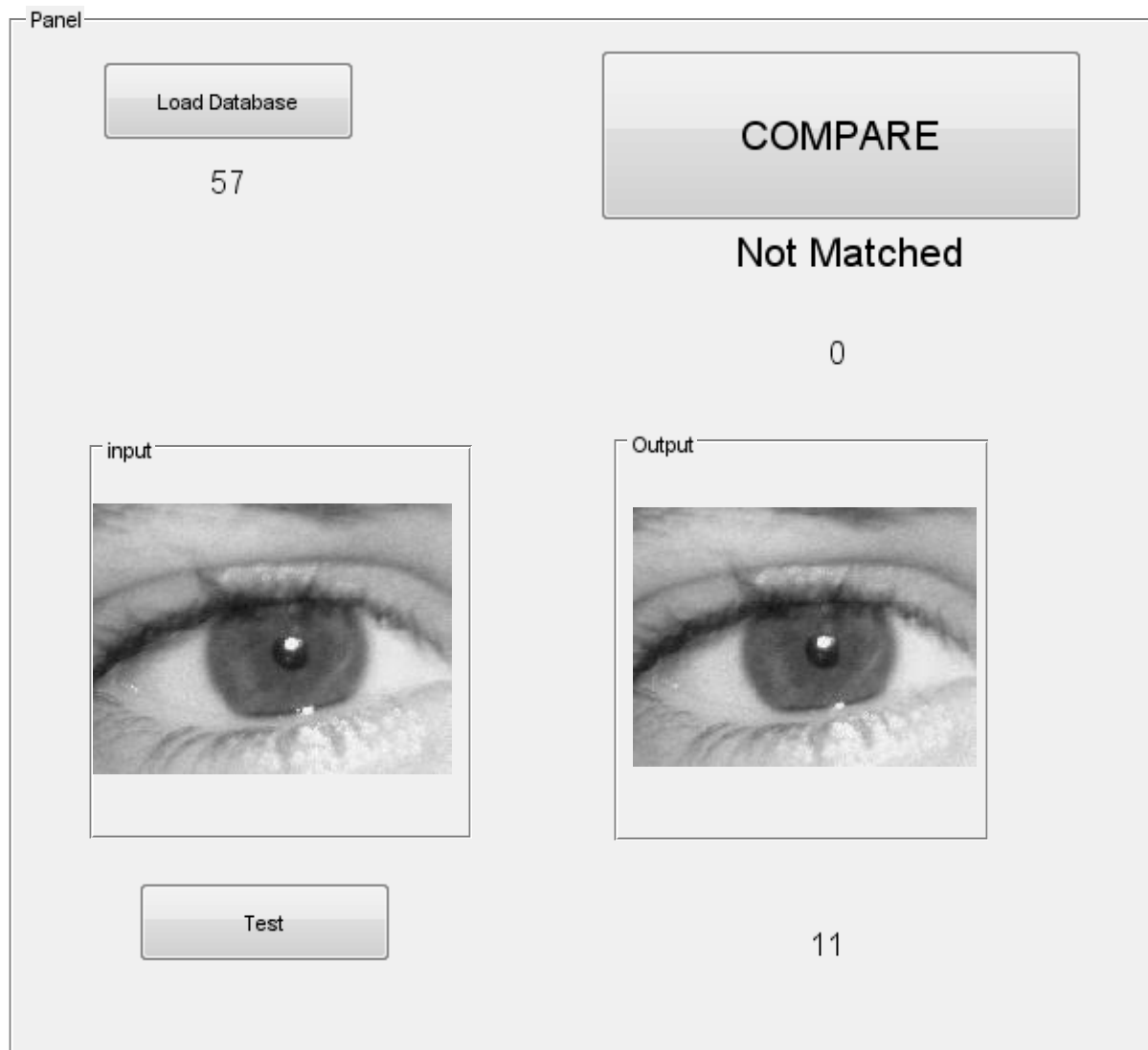


Figure 20: GUI showing input image, output image and results (Example 8)

9. Conclusion

The iris biometric recognition system has its countless applications as it gives security due to its nature as independent from operator. The evolving need for safer admittance in building, secured areas needs passive and non-invasive technique that have high performance and better accuracy. But under the influence of occlusions such as glare, spectacles tend to produce inaccurate results. So we pre-processed the damaged or corrupted image using mean filtered inpainting technique. The experimental validation showed a significant increase in accuracy of the iris recognition system. Also, the performance can be further improved. The performance of the system can be improved by the use of more updated or advanced equipment such as using a high quality camera for capturing eye images, updated system, other parameters and circumstances in which the image is being captured.

10.Scope for future Development

Future work include implementation of:

- The time taken in complete analysis is much high mainly due to image inpainting. This code need to be optimized or a new code is to be developed. Making this code accessible for all type of iris and for all size.
- Algorithm need to be developed for iris taken at different angle and distance.
- Code need to be developed for real time analysis.
- Hardware implementation.

11. References

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